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B70 12089

SUBJECT: Performance Capabilities of the Apollo 14 CSM and LM Downlink Communications - Case 320

DATE: December 31, 1970

FROM: N. W. Schroeder

ABSTRACT

Margin calculations for Apollo 14 have been performed using the communication system parameters available from the Apollo 12 mission. The results of these calculations are tabulated giving both the predicted power margins and also the maximum usable ranges of selected Apollo communications services.

Some of the results for non standard configurations are the following:

1) Maximum range for color television with positive margin, received at a DSN 210' station from the bore sight of a CSM omni antenna is about 51,000 nm. Degraded pictures may be usable out to about 70,000 nm.

2) Low bit rate telemetry can be received up to lunar range with a BER $\approx 10^{-6}$ by an MSFN 85' ground station for transmissions from omni antennas on both the CSM and the LM.

3) A DSN 210' ground station is required to receive with positive margins, frequency modulated transmissions of dual EVA data from a LM steerable antenna at lunar range.

4) A DSN 210' ground station is also required to receive low power phase modulated transmissions of 51.2 KBPS telemetry data with a BER $\approx 10^{-6}$ from a LM steerable antenna at lunar range.

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MEMORANDUM FOR FILE

I. Introduction

Communications performance predictions have been
calculated for the CSM and LM downlink channels using the
Apollo 12 mission performance data given in Table VII and
Reference 1. The calculations, except for the modes with
base band voice modulation, which are contained in Appendix A,
were performed using the power margin equations contained
in Reference 2. The analysis contained in this memorandum
includes tabulations of predicted power margins for selec-
ted downlink services of the possible downlink antenna
combinations between the LM, CSM, MSFN 85' and DSN 210';
in the downlinks using omni antennas, both the nominal case
and the special case of "on axis or bore sight" transmissions
are considered. For the CSM, tabulations of maximum communi-
cations ranges of selected downlinks are also included.

II. Results

Results of this analysis are summarized in Tables I
thru IV. Table I shows the maximum communication ranges pre-
dicted for transmissions from the CSM omni antennas assuming
that the +5db bore sight gain of these antennas can be utilized.
Table II is similar to Table I but here maximum range predic-
tions for both the CSM omni antennas (assuming zero dB gain)
and the narrow beam CSM steerable antenna transmissions are
shown. Tables III and IV show the predicted power margins
for selected downlink services transmitted from the CSM and LM
respectively; in these two tables the margins for the omni an-
tennas are calculated using gains of zero and -3dB for the CSM
and LM omni antennas respectively. Note that in Tables I-IV
the magnitudes shown for total received signal power, labelled
P_r, and the total required received power, labelled P_{min}, are
taken from Tables V and VI.

III. Discussion of Results

Maximum range calculations for bore sight trans-
missions from the CSM omni antennas show that in the phase

modulation modes, low bit rate telemetry and voice can be re-
ceived with positive margins, at an MSFN 85' station up to
lunar range and in the frequency modulation mode television can
be received at a DSN 210' station up to 51,000 nautical miles.
To utilize the 5db bore sight antenna gain, reference 3 indi-
cates that the CSM's attitude needs to be remained fixed to
within ± 30 degrees.

Maximum range calculations for high power transmissions
from the CSM steerable - HGA(N) antenna show that all mission
data except color television can be received with positive mar-
gins at an MSFN 85' station up to lunar range. In this antenna
configuration the maximum predicted range for reception of
color television with positive margins is 151,000 nautical miles.

Table IV

Power margin calculations summarized in Table IV
for possible downlink LM antenna configurations up-date and
expand the analysis recently presented in Reference 4. The
results in Reference 4 were intended to be based on Apollo 12
mission parameters; however, some earlier parameter values
were inadvertently used that differed slightly from the Apollo 12
data. The corrected results show some improvements in the pre-
dicted performance from that reported in Reference 4; however,
this improvement is only significant toward achieving positive
margins in cases where the LM is transmitting in the low power
mode.

From Reference 5 "LM Antenna Systems Performance,"
James S. Kelly, NASA/MSC, December 1967, it appears that a
zero db gain can be achieved by the LM omni antennas over about
77% of its surrounding sphere. With LM omni antenna gains of
zero db, low bit rate telemetry could be received by an MSFN
85' with a Bit Error Rate (BER) = 10^{-6} and high bit rate
telemetry could be received by a DSN 210' with BER $\approx 10^{-4}$.

Television

Television performance is discussed above and is
presented in Tables I-IV only in terms of the specified
threshold performance of television for Apollo 12. Regard-
less of the basis used for selecting this "threshold" perfor-
mance, arguments can be raised in specific cases for defining
a degraded picture "usable" in scenes where detail is not re-
quired and where that performance is all that is available.

Television received at an MSFN 85' station from a CSM steerable antenna at lunar range has been claimed to be "usable" in Reference 6. If this degree of degradation is considered acceptable for a selected scene, then the "usable" range for a color picture transmitted to a DSN 210' station from the bore sight of a CSM omni antenna can be extended from the 51,000 nautical miles stated in Table I to at least 70,000 nautical miles.

Conclusions

Margin calculations predict the following significant capabilities for special Apollo spacecraft links:

CSM

1. Television can be transmitted with positive margins from the bore sight of a CSM omni antenna to a DSN 210' station up to a maximum of about 51,000 nautical miles. A degraded but "usable" picture may be received up to about 70,000 nautical miles in this antenna configuration.

2. Low bit rate telemetry and voice in the phase modulated mode can be received with positive margins at an MSFN 85' station from the bore sight of a CSM omni antenna up to lunar range.

LM

1. Low bit telemetry (BER $\approx 10^{-6}$) in the phase modulated mode can be received at an MSFN 85' station when transmitted from the bore sight of a LM omni antenna at lunar range.

2. A DSN 210' antenna is required to receive, with positive margins, dual EVA data transmitted from a LM steerable antenna at lunar range.

3. A DSN 210' antenna is required to receive, with positive margins, high bit rate telemetry data (BER $\approx 10^{-6}$) transmitted at low power from a LM steerable antenna at lunar range.

2034-NWS-ms   N. W. Schroeder

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REFERENCES

1. "Communication Systems Performance and Coverage Analysis for Apollo 12 (H-1 Mission)" Volume 1, F. J. Lock, T. W. Eggleston, J. A. Porter, MSC Internal Note No. MSC-00-173, October 2, 1969.

2. "Communications Margins for Apollo Unified S-Band Links With Phase Modulation." Bellcomm Technical Memorandum TM68-2034-17, N. W. Schroeder, December 31, 1968.

3. "Full Scale Block II Command and Service Module S-Band Omni Antenna Patterns," Jefferson F. Lindsey, III; MSC Internal Note No. 67EE15, June 1967, NASA/MSC.

4. "Effects of Deletion of LM Erectable Antenna on LM-MSFN Communications," Bellcomm, Inc., Memorandum for File B70-09082, September 30, 1970, N. W. Schroeder.

5. "LM Antenna Systems Performance," James S. Kelly, NASA/MSC, December, 1967.

6. "Alternative Designs for the Television Transmission System of the Lunar Communications Relay Unit (LCRU) and their Communication Link Performance, Bellcomm, Inc. Memo. for File B70-02039, R. L. Selden, February 4, 1970.

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Appendix A

Power Margin Equations
for Those Modulation
Modes with Base Band Voice

The following power margin equations have been derived in a manner similar to that used in Reference 2 of the text and differ from them only with regard to the changes necessary to incorporate the base band voice modes.

The downlink signal is assumed to be of the form

$$S_d(t) + n_d(t) = \sqrt{2P_{gr}}\, \sin(\omega_{dc}t + R_g \sin\omega_x t + y) + n_d(t) \qquad \text{A-1}$$

$$\omega_x t = m_1 \sin\omega_1 t + n_2 \sin\omega_2 t + \Theta$$

$$y = m_3 \sin\omega_3 t + m_4 \sin\omega_4 t + m_5 + n_r$$

P_{gr} = Total received signal power at the ground receiver

ω_{dc} = Down carrier frequency in radians/second

$$R_g = R_o \left[\frac{(S/N)_{us}}{\frac{1}{k_{us}} + (S/N)_{us}} \right]^{1/2} \quad \begin{array}{l}\text{= Gain of the transponder}\\ \text{turn around channel}\end{array}$$

$$R_o = \frac{\sqrt{2}}{2}\, L_{us} B\, G = \begin{array}{l}\text{Transponder constant for turn}\\ \text{around channel}\end{array}$$

L_{us} = Power output of the limiter in the transponder video channel.

$\dfrac{B}{2}$ = Gain of the transponder coherent carrier product detector.

G = Combined gain of the transponder IF channel and modulator.

$$(S/N)_{us} = \frac{P_{sr}}{K_o T_u B_{ts}} = \text{signal to noise power ratio at the input to the limiter in the transponder video channel}$$

P_{sr} = total received signal power at the transponder input

$K_o = 1.38 \times 10^{-23}$ watts/°KHz = Boltzmann's constant

$T_u = A_u + B_u P_{uc}$ = noise temperature referred to transponder in degrees Kelvin

A_u, B_u = transponder noise temperature constants

P_{uc} = up carrier signal power received at the transponder

B_{ts} = input bandwidth of the limiter in the transponder video channel

m_1, m_2 = up subcarrier peak modulator indexes in radians

m_3, m_4 = down subcarrier peak modulation indexes in radians

ω_1, ω_2 = up subcarrier frequencies in radians/second

ω_3, ω_4 = down subcarrier frequencies in radians/second

Θ = peak modulation index in radians of pseudo random range code

$$n_r^2 \simeq \frac{N_u^2}{2} = \text{approximation of the thermal noise power retransmitted by the transponder.}$$

$$N_u = R_o \left[\frac{1}{1 + k_{us} (\frac{S}{N})_{us}} \right]^{1/2} \left[\frac{B_v}{\frac{B_{ts}}{2}} \right]^{1/2}$$

k_{us} = $\Pi/4$ for $(S/N)_{us} \leq .035$ ⎫
⎪ limiter factor for
= $.68$ $(S/N)_{us}$ + $.76$ for $.035 < .35$ ⎬ limiter in transponder
⎪ video channel
= 1 for $(S/N)_{us} \geq .35$ ⎭

B_v = Bandwidth of the transponder video channel

m_5 = Effective peak modulation for the baseband back-up voice modulated directly on carrier.

$n_d(t)$ = Thermal noise added to received signal by ground receiver

Downlink Subcarriers

$$\text{Power Margin} = 10 \log_{10} \left[P_{gr} \Big/ P_{\min \omega_i} \right] \qquad\qquad \text{A-2}$$

$$P_{\min \omega_i} = \frac{A_d B_{\omega_i} {}^\gamma d\omega_{ir} K_o}{2k_{ds} \left[\alpha_{d\omega_i} - {}^\gamma d\omega_{ir} \, \eta_\omega \right] - \alpha_{dc} B_d B_{\omega_i} {}^\gamma d\omega_{ir} K_o}$$

$$\alpha_{dc} = J_o^2(R_g) J_o^2(N_u) J_o^2(m_i) J_o^2(m_j) \cos^2(m_5)$$

$$\alpha_{d\omega_i} = J_o^2(R_g) J_o^2(N_u) J_1^2(m_i) J_o^2(m_j) \cos^2(m_5)$$

$$\eta_\omega = J_o^2(R_g) J_1^2(N_u) J_o^2(m_3) J_o^2(m_4) \cos^2(m_5) \frac{B_{\omega_i}}{B_v}$$

$${}^\gamma d\omega_{ir} = \text{Antilog}_{10} \left[\begin{array}{l} \text{Required signal to noise ratio} \\ \text{in dB for threshold perfor-} \\ \text{mance of subcarrier channel} \\ \text{divided by 10.} \end{array} \right]$$

$B\omega_i$ = Predetection bandwidth of subcarrier channel.

$i = 3$ or 4

$j = 3$ or 4

$\quad i \neq j$

k_{ds} is identical to k_{us} except that $(S/N) =$

$$P_{gr} \Big/ K_o B_{gs} T_d$$

B_{gs} = Input bandwidth of limiter in the ground station video channel

Range Code

Power Margin = $10 \log_{10} \left[P_{gr} \Big/ P_{min\ co} \right]$ A-3

$$P_{min\ co} = \frac{A_d \gamma_{dcor} K_o}{4\alpha_{dco} - \alpha_{dc} B_d \gamma_{dcor} K_o - \gamma_{dcor}\ \eta_c}$$

$$\alpha_{dco} = J_1^2(R_g) J_0^2(N_u) J_0^2(m_1) J_0^2(m_2) J_0^2(m_3) J_0^2(m_4) \sin^2\Theta \cos^2 m_5$$

γ_{dcor} = Antilog$_{10}$ $\left[\begin{array}{l} \text{Required signal to noise ratio in dB} \\ \text{for threshold performance of ranging} \\ \text{channel divided by 10.} \end{array} \right]$

$$\eta_c = 2 J_0^2(R_g) J_1^2(N_u) J_0^2(m_3) J_0^2(m_4) \cos^2 m_5 \Big/ B_v$$

Baseband Voice

Power Margin = $10 \log_{10} \left[P_{gr} \Big/ P_{mindv} \right]$ A-4

$$P_{min\ v} = \frac{A_d\ B_{bv}\ \gamma_{dv}\ r^{K_o}}{\alpha_{dv}k_{dc} - \gamma_{dvr}^{K_o}\ B_{dv}\ \alpha_{dc}B_d - 2\ \gamma_{dvr}k_{dc}\eta_{dv}}$$

$$\alpha_{dv} = J_o^2(R_g)J_o^2(N_u)J_o^2(m_3)J_o^2(m_4)\sin^2 m_5$$

$$\eta_{dv} = J_o^2(R_g)J_1^2(N_u)J_o^2(m_3)J_o^2(m_4)\cos^2 m_5\ \frac{B_{dv}}{B_v}$$

B_{dv} = Post detection bandwidth of base band voice

k_{dc} is identical to k_{us} except that

$$(S/N) = P_{gr}\ \alpha_{dc}\ \Big/\ K_o T_d B_{dc}$$

B_{dc} = Bandwidth of downlink carrier tracking loop.

TABLE I

SUMMARY OF MAXIMUM RANGES† FOR COMMUNICATIONS SERVICES

FROM CSM OMNI* ANTENNAS

ANTENNA/GROUND STATION	PA	VOICE & BIOMED DATA				TELEMETRY					TELEVISION	
		FM	PM WITH TELEMETRY			FM (BER = 10⁻⁴)		PM (BER = 10⁻⁶)				
		32:1 PLAYBACK VOICE	FULL MODE HBR	HBR	LBR	1:1 PLAYBACK HBR	32:1 PLAYBACK SPLIT PHASE LM LBR	FULL MODE HBR	WITH VOICE HBR	WITH VOICE LBR	B & W	COLOR
P_{MIN} (dBW) →		-135.2	-141.7	-142.2	-146.4	-136.0	-133.1	-138.4	-139.0	-150.0	-132.5	-124.0
P_r (dBW) ↓												
OMNI (A)/210'	OFF -156.5	19,000	39,000	41,000	67,000	20,000	15,000	27,000	29,000	102,000	14,565	5,100
OMNI (A)/210'	ON -136.5	185,000	+	+	+	203,000	145,000	+	+	+	136,000	51,000
OMNI (C)/210'	OFF -158.5	15,000	31,000	33,000	53,000	16,000	12,000	21,000	23,000	81,000	11,000	4,000
OMNI (C)/210'	ON -138.5	147,000	+	+	+	161,000	115,000	213,000	+	+	108,000	40,000
OMNI (A)/85'	OFF -164.5	7,000	16,000	16,000	27,000	8,000	6,000	11,000	11,000	40,000	5,000	2,000
OMNI (A)/85'	ON -144.5	74,000	157,000	165,000	+	81,000	58,000	107,000	114,000	+	54,000	20,000
OMNI (C)/85'	OFF -166.5	6,000	12,000	13,000	21,000	6,000	5,000	8,000	9,000	32,000	4,000	2,000
OMNI (C)/85'	ON -146.5	59,000	125,000	131,000	213,000	64,000	46,000	85,000	91,000	+	43,000	16,000

† RANGES ARE GIVEN IN NAUTICAL MILES

* OMNI ANTENNA GAINS = +5 dB

+ MAXIMUM RANGE EXCEEDS 215,000 NAUTICAL MILES

TABLE II
SUMMARY OF MAXIMUM RANGES† FOR COMMUNICATIONS SERVICES FROM A CSM

ANTENNA/GROUND STATION	PA	VOICE & BIOMED DATA				TELEMETRY					TELEVISION	
		FM	PM			FM (BER = 10^{-4})		PM (BER = 10^{-6})				
		32:1 PLAYBACK VOICE	FULL MODE HBR	WITH TELEMETRY		1:1 PLAYBACK HBR	32:1 PLAYBACK SPLIT PHASE LM LBR	FULL MODE HBR	WITH VOICE		B & W	COLOR
				HBR	LBR				HBR	LBR		
P_{MIN} (dBW) →		− 135.2	− 141.7	− 142.2	− 146.4	− 136.0	− 133.1	− 138.4	− 139.0	− 150.0	− 132.5	− 124.0
P_r (dBW) →												
HGA (N)*/85' −147.1	OFF	55,000	117,000	123,000	198,000	60,000	43,000	81,000	85,000	+	40,000	15,000
HGA (N)*/85' −127.1	ON	+	+	+	+	+	+	+	+	+	+	151,000
HGA (N)*/210' −139.1	OFF	138,000	+	+	+	151,000	108,000	203,000	213,000	+	101,000	38,000
HGA (N)*/210' −119.1	ON	+	+	+	+	+	+	+	+	+	+	+
OMNI (A)*/85' −169.5	OFF	4,000	9,000	9,000	15,000	5,000	3,000	6,000	6,000	22,000	3,000	1,000
OMNI (A)*/85' −149.5	ON	42,000	89,000	93,000	150,000	46,000	33,000	61,000	64,000	+	30,000	11,000
OMNI (A)*/210' −161.5	OFF	10,000	22,000	23,000	38,000	11,000	8,000	15,000	16,000	56,000	8,000	3,000
OMNI (A)*/210' −141.5	ON	104,000	+	+	+	115,000	82,000	154,000	161,000	+	77,000	29,000
OMNI (C)*/85' −171.5	OFF	3,000	7,000	7,000	12,000	4,000	3,000	5,000	5,000	18,000	2,000	900
OMNI (C)*/85' −151.5	ON	33,000	70,000	74,000	119,000	36,000	26,000	49,000	51,000	178,000	24,000	9,000
OMNI (C)*/210' −163.5	OFF	8,000	18,000	19,000	30,000	9,000	7,000	12,000	13,000	45,000	6,000	2,000
OMNI (C)*/210' −143.5	ON	83,000	177,000	186,000	+	91,000	65,000	122,000	128,000	+	61,000	23,000

† RANGES ARE GIVEN IN NAUTICAL MILES

* CSM OMNI ANTENNA GAINS = 0 dB

+ MAXIMUM RANGE EXCEEDS 215,000 NAUTICAL MILES

ANTENNA/GROUND STATION	PA	VOICE & BIOMED DATA				TELEMETRY					TELEVISION	
		FM	PM			FM (BER = 10^{-4})		PM (BER = 10^{-6})				
		32:1 PLAYBACK VOICE	FULL MODE HBR	WITH TELEMETRY		1:1 PLAYBACK HBR	32:1 PLAYBACK SPLIT PHASE LM LBR	FULL MODE HBR	WITH VOICE		B & W	COLOR
				HBR	LBR				HBR	LBR		
P_{MIN} (dBW) →		-135.2	-141.7	-142.2	-146.4	-136.0	-133.1	-138.4	-139.0	-150.0	-132.5	-124.0
P_r (dBW) ↓												
HGA (N)/85' -147.1	OFF	-11.9	-5.4	-4.9	-0.7	-11.1	-14.0	-8.7	-8.1	+	-14.6	-23.1
HGA (N)/85' -127.1	ON	+	+	+	+	+	+	+	+	+	+	-3.1
HGA (N)/210' -139.1	OFF	-3.9	+	+	+	-3.1	-6.0	-0.7	-0.1	+	-6.6	-15.1
HGA (N)/210' -119.1	ON	+	+	+	+	+	+	+	+	+	+	+
OMNI (A)/85' -169.5	OFF	-34.3	-27.8	-27.3	-23.1	-33.5	-36.4	-31.1	-30.5	-19.5	-37.0	-45.5
OMNI (A)/85' -149.5	ON	-14.3	-7.8	-7.3	-3.1*	-13.5	-16.4	-11.1	-10.5	+	-17.0	-25.5
OMNI (A)/210' -161.5	OFF	-26.3	-19.8	-19.3	-15.1	-25.5	-28.4	-23.1	-22.5	-11.5	-29.0	-37.5
OMNI (A)/210' -141.5	ON	-6.3	+	+	+	-5.5	-8.4	-3.1*	-2.5*	+	-9.0	-17.5
OMNI (C)/85' -171.5	OFF	-36.3	-29.8	-29.3	-25.1	-35.5	-38.4	-33.1	-32.5	-21.5	-39.0	-47.5
OMNI (C)/85' -151.5	ON	-16.3	-9.8	-9.3	-5.1*	-15.5	-18.4	-13.1	-12.5	-1.5*	-19.0	-27.5
OMNI (C)/210' -163.5	OFF	-28.3	-21.8	-21.3	-17.1	-27.5	-30.4	-25.1	-24.5	-13.5	-31.0	-39.5
OMNI (C)/210' -143.5	ON	-8.3	-1.8*	-1.3*	+	-7.5	-10.4	-5.1*	-4.5*	+	-11.0	-19.5

† POWER MARGINS ARE GIVEN IN DECIBELS

* MARGINS WOULD BE POSITIVE ASSUMING A +5 dB (BORE SIGHT)
  GAIN FOR THE CSM OMNI ANTENNAS

+ POWER MARGIN EXCEEDS ZERO

TABLE IV
SUMMARY OF POWER MARGINS† (dB) FOR COMMUNICATIONS FROM A LM
AT LUNAR RANGE (R = 215,000 N. MI.)

ANTENNA/GROUND STATION	P_r (dBW)	PA	VOICE & BIOMED DATA — FM — EVCS DUAL EVA WITH TELEVISION	VOICE & BIOMED DATA — PM — FULL MODE HBR	VOICE & BIOMED DATA — PM — WITH TELEMETRY — HBR	VOICE & BIOMED DATA — PM — WITH TELEMETRY — LBR	TELEMETRY — FM (BER = 10^{-4}) — HBR WITH TELEVISION	TELEMETRY — FM (BER = 10^{-4}) — LBR WITH TELEVISION	TELEMETRY — PM (BER = 10^{-6}) — FULL MODE HBR	TELEMETRY — PM (BER = 10^{-6}) — WITH VOICE — HBR	TELEMETRY — PM (BER = 10^{-6}) — WITH VOICE — LBR	TELEVISION — B & W	TELEVISION — COLOR
P_{MIN} (dBW) →			- 126.6	- 141.4	- 142.1	- 146.7	- 131.6	- 140.2	- 139.5	- 140.2	- 149.2	- 132.5	- 124.0
STEERABLE/85'	- 147.8	OFF	- 21.2	- 6.4	- 5.7	- 1.1	- 16.2	- 7.6	- 8.3	- 7.6	+	- 15.3	- 23.8
STEERABLE/85'	- 130.4	ON	- 3.8	+	+	+	+	+	+	+	+	+	- 6.4
STEERABLE/210'	- 139.8	OFF	- 13.2	+	+	+	- 8.2	+	- 0.3†	+†	+	- 7.3	- 15.8
STEERABLE/210'	- 122.4	ON	+	+	+	+	+	+	+	+	+	+	+
ERECTABLE/85'	- 139.6	OFF	- 13.0	+	+	+	- 8.0	+	- 0.1†	+	+	- 7.1	- 15.6
ERECTABLE/85'	- 122.2	ON	+	+	+	+	+	+	+	+	+	+	+
ERECTABLE/210'	- 131.6	OFF	- 5.0	+	+	+	0†	+	+	+	+	+	- 7.6
ERECTABLE/210'	- 114.2	ON	+	+	+	+	+	+	+	+	+	+	+
OMNI/85'	- 152.3	ON	- 25.7	- 10.9	- 10.2	- 5.6	- 20.7	- 12.1	- 12.8	- 12.1	- 3.1*	- 19.8	- 28.3
OMNI/210'	- 144.3	ON	- 17.7	- 2.9*	- 2.2*	+	- 12.7	- 4.1	- 4.3	- 4.1	+	- 11.8	- 20.3

† NOTE IMPROVEMENT FROM THAT REPORTED IN REFERENCE 4

+ POWER MARGIN EXCEEDS ZERO

* MARGINS WOULD BE POSITIVE ASSUMING A ZERO dB (BORE SIGHT)
  GAIN FOR THE LM OMNI ANTENNAS

TABLE V

TOTAL RECEIVED SIGNAL POWER AT A GROUND STATION

GROUND STATION ANTENNA	LM			CSM		
		RECEIVED SIGNAL POWER			RECEIVED SIGNAL POWER	
	ANTENNA	LM TRANSMITTING HIGH POWER (18.6 WATTS)	LM TRANSMITTING LOW POWER (.34 WATTS)	ANTENNA	CSM TRANSMITTING HIGH POWER (12.5 WATTS)	CSM TRANSMITTING LOW POWER (.125 WATTS)
DSN (210')	ERECTABLE	- 114.2 dBW	- 131.6 dBW	HGA (N)	- 119.1 dBW	- 139.1 dBW
	STEERABLE	- 122.4	- 139.8	HGA (M)	- 126.5	- 146.5
	OMNI*	- 144.3	- 161.7	HGA (W)	- 136.4	- 156.4
				OMNI (A)**	- 141.5	- 161.5
				OMNI (C)**	- 143.5	- 163.5
MSFN (85')	ERECTABLE	- 122.2	- 139.6	HGA (N)	- 127.1	- 147.1
	STEERABLE	- 130.4	- 147.8	HGA (M)	- 134.5	- 154.5
	OMNI*	- 152.3	- 169.7	HGA (W)	- 144.4	- 164.4
				OMNI (A)**	- 149.5	- 169.5
				OMNI (C)**	- 151.5	- 171.5
MSFN (30')	ERECTABLE	- 131.2	- 148.6	HGA (N)	- 136.1	- 156.1
	STEERABLE	- 139.4	- 156.8	HGA (M)	- 143.5	- 163.1
	OMNI*	- 161.3	- 178.7	HGA (W)	- 153.4	- 173.4
				OMNI (A)**	- 158.5	- 178.5
				OMNI C)**	- 160.5	- 180.5

* LM OMNI ANTENNA GAIN = - 3 dB

** CSM OMNI ANTENNA GAIN = 0 dB

TABLE VI

TOTAL RECEIVED SIGNAL POWER REQUIRED FOR THRESHOLD PERFORMANCE
OF APOLLO COMMUNICATIONS CHANNELS

PHASE MODULATION MODES

CHANNEL W/OTHER SERVICES TRANSMITTED SIMULTANEOUSLY	CSM			LM		
	MODE		SIGNAL POWER (dBW)	MODE		SIGNAL POWER (dBW)
	UP	DOWN		UP	DOWN	
(USING A DSN-210' OR MSFN-85' GROUND STATION POINTING TO THE MOON AT ZENITH)						
1. 51.2 KBPS TLM W/ 1) FULL MODE*	6	2	– 138.4	6	2	– 139.5
2. 2) VOICE/BIOMED DATA	–	1	– 139.0	–	1	– 140.2
3. 3) 51.2 KBPS TLM ONLY	–	13	– 141.1	–	13	– 142.0
4. VOICE/BIOMED DATA W/ 1) FULL MODE* - HBR TLM	6	2	– 141.7	6	2	– 141.4
5. 2) FULL MODE* - LBR TLM	6	3	– 146.0	–	–	–
6. 3) 51.2 KBPS TLM	–	1	– 142.2	–	1	– 142.1
7. 4) 1.6 KBPS TLM	–	4	– 146.4	–	7	– 146.7
8. 5) VOICE/BIOMED ONLY	–	12	– 147.3	–	12	– 145.7
9. 1.6 KBPS TLM W/ 1) FULL MODE*	6	3	– 149.5	–	–	–
10. 2) VOICE/BIOMED DATA	–	4	– 150.0	–	7	– 149.2
11. 3) BASE BAND VOICE	–	8	– 150.7	–	4	– 148.3
12. 4) 1.6 KBPS TLM ONLY	–	5	– 158.0	–	3	– 157.2
13. BASEBAND VOICE W/ 1) 1.6 KBPS TLM	–	8	– 162.2	–	4	– 162.1
14. 2) BASE BAND VOICE ONLY	–	10	– 166.6	–	5	– 166.3
15. RANGING W/ 1) FULL MODE - HBR TLM	6	2	– 148.3* – 150.7**	6	2	– 146.3[†] – 149.8[††]
16. 2) FULL MODE - LBR TLM	6	3	– 147.0	–	–	–
17. 3) RANGING ONLY	1	7	– 163.4*	1	11	– 164.2[†]
18. KEY ONLY	–	6	– 179.4	–	6	– 181.2

*   CALCULATED FOR CSM OMNI - MSFN 85' LINK

**   CALCULATED FOR CSM HGA(N) - DSN 210' LINK

†   CALCULATED FOR LM OMNI - MSFN 85' LINK

††   CALCULATED FOR LM ERECTABLE - DSN 210' LINK

TABLE VI (CONTINUED)

TOTAL RECEIVED SIGNAL POWER REQUIRED FOR THRESHOLD PERFORMANCE OF APOLLO COMMUNICATIONS CHANNELS

FREQUENCY MODULATION MODES

CHANNEL	SIGNAL POWER (dBW)
(USING DSN-210' OR MSFN-85' GROUND STATION POINTING TO THE MOON AT ZENITH)	
CSM	
1. 1:1 PLAY BACK VOICE (70% WORD INTELLIGIBILITY)	− 139.0
2. 32:1 PLAY BACK VOICE (70% WORD INTELLIGIBILITY)	− 135.2
3. 1:1 PLAY BACK 51.2 KBPS TLM (BER = 10^{-4})	− 136.0
4. 32:1 PLAY BACK 1.6 KBPS TLM (BER = 10^{-4})	− 136.0
5. 32:1 PLAY BACK 1.6 KBPS LM (BER = 10^{-4}) SPLIT PHASE TLM	− 133.1
6. TELEVISION (BLACK AND WHITE)	− 132.5
7. TELEVISION (COLOR)	− 124.0
LM	
8. VOICE (90% WORD INTELLIBIBILITY)	− 132.0
9. 51.2 KBPS TLM WITH TELEVISION	− 131.6
10. 51.2 KBPS TLM NO TELEVISION	− 133.2
11. 1.6 KBPS TLM WITH TELEVISION	− 140.2
12. 1.6 KBPS TLM NO TELEVISION	− 141.8
13. EVA (DUAL) WITH TELEVISION	− 126.6
14. EVA (DUAL) NO TELEVISION	− 127.6
15. TELEVISION (BLACK AND WHITE)	− 132.5
16. TELEVISION (COLOR)	− 124.0

TABLE VII

USB SYSTEM PARAMETERS USED IN CALCULATING
COMMUNICATIONS MARGINS
(TAKEN FROM APOLLO 12 DATA)

PARAMETER	GROUND STATION	CSM	LM	UNITS
RECEIVE CARRIER	2282.5 (LM) 2287.5 (CSM-PM) 2272.5 (CSM-FM)	2106.406	2101.8	MHz
NSD CONSTANT A	210 (MSFN 85' AND MSFN 210' STATION)	5800	3600	DEGREES KELVIN
NSD CONSTANT B	3.05	.0275	.126	$\times 10^{15}$ DEG/WATT
IF BANDWIDTH	4.8	4.6	4.8	MHz
VIDEO BANDWIDTH	–	1.7	1.8	MHz
RANGING CHANNEL CONSTANT	–	.44	.55	–
CARRIER LOOP BANDWIDTH	50	800	1100	Hz
POINTING LOSS	0	0 (OMNI) 0.2 (HGA)	0 (OMNI) 0.5 (STEERABLE) 2.0 (ERECTABLE)	dB
POLARIZATION LOSS	0	0	0	dB
TRANSMIT POWER	10^4	13.3 (HIGH-FM) 12.5 (HIGH-PM) .125(LOW)	18.6 (HIGH) .34(LOW)	WATTS
ANTENNA GAINS (TRANSMIT)	52.5 (MSFN 85') 60.5 (DSN 210') 43.0 (MSFN 30')	0 (OMNI) 8.5 [HGA-W] 18.4 [HGA-M] 25.8 [HGA-N]	– 3 (OMNI) 20.5 (STEERABLE) 34.0 (ERECTABLE)	dB
ANTENNA GAINS (RECEIVE)	53 (MSFN 85') 61 (DSN 210') 44 (MSFN 30')	(OMNI) 7 [HGA-W] 24.4 [HGA-M] 24.9 [HGA-N]	– 3.0 (OMNI) 16.5 (STEERABLE) 31.7 (ERECTABLE)	dB
TRANSMIT CIRCUIT LOSS	0	– 1.8 (OMNI-A) – 3.8 (OMNI-C) – 5.0 (HGA)	– 3.4 (OMNI) – 4.5 (STEERABLE) – 8.3 (ERECTABLE)	dB
RECEIVE CIRCUIT LOSS	0	– 2.5 (OMNI-A) – 4.5 (OMNI-C) – 5.6 (HGA)	– 5.4 (OMNI) – 6.0 (STEERABLE) –10.3 (ERECTABLE)	dB
REQUIRED SIGNAL/NOISE RATIOS PM				
– CARRIER	12.0	12.0	12.0	dB
– UP VOICE (FOR 90% WORD INTELLI-GIBILITY)	–	10.0	10.0	dB
– UP DATA (FOR A MAXIMUM MESSAGE REJECTION OF ONE PER 1000)	–	10.0	10.0	dB
– DOWN VOICE WITH BIOMED (FOR 90% WORD INTELLIGIBILITY)	8.0	–	–	dB
– TLM - 51.2 KBPS (FOR A BER = 10^{-6})	8.0	–	–	dB
– TLM - 1.6 KBPS (FOR A BER = 10^{-6})	5.9	–	–	dB
– RANGING (FOR A MAXIMUM ACQUI-SITION TIME OF 60 SECONDS)	32.0	–	–	dB
– BASEBAND VOICE	4.0	–	–	dB
– EMERGENCY KEY	– 10.5	–	–	dB
PREDETECTION BANDWIDTHS				
– UP VOICE	–	22.0	22.0	kHz
– UP DATA	–	22.0	23.0	kHz
– DOWN VOICE (SUBCARRIER) (WITH BIOMED DATA)	42.0	–	–	kHz
– DOWN VOICE (BASEBAND)	2840.0	–	–	Hz
– TLM - 51.2 KBPS	180.0	–	–	kHz
– TLM - 1.6 KBPS	7250.0	–	–	Hz
– KEY	1350.0	–	–	Hz
– RANGING	1.0	–	–	Hz
RHO (FOR PM BACK UP VOICE, 24 dB CLIPPING)	–	.66	.66	–

TABLE VII (CONTINUED)

MODULATION INDICES IN RADIANS FOR THE PM MODES

	MODE	UPVOICE	UPDATA	RANGING		
UPLINK (CSM AND LM)	1	–	–	1.34		
	2	1.85	–	–		
	3	–	1.85	–		
	4	1.2	–	.38		
	5	–	1.2	.38		
	6	1.0	1.0	.44		
	7	1.1	1.1	–		
	8	1.2	–	.38		
	MODE	NORMAL VOICE	HBR TELEMETRY	LBR TELEMETRY	BASEBAND VOICE	COMMENTS
DOWNLINK (CSM)	1	.70	.96	–	–	
	2	.70	.96	–	–	WITH RANGING
	3	1.2	–	.70	–	WITH RANGING
	4	1.2	–	.70	–	
	5	–	–	1.6	–	
	6	–	–	1.0	–	EMERGENCY KEY
	7	–	–	–	–	RANGING ONLY
	8	–	–	1.2	.70	
	9	–	–	1.6	–	WITH RANGING
	10	–	–	–	1.2	
	11	1.2	–	–	–	WITH RANGING
	12	1.2	–	–	–	
	13	–	1.1	–	–	
	14	–	1.1	–	–	WITH RANGING
DOWNLINK (LM)	1	.9	1.3	–	–	
	2	.9	1.3	–	–	WITH RANGING
	3	–	–	1.3	–	
	4	–	–	1.3	.80	
	5	–	–	–	.80	
	6	–	–	1.4	–	EMERGENCY KEY
	7	1.3	–	.70	–	LOW POWER MODE
	8	.73	–	1.3	–	WITH BIOMED SUBCARRIERS
	11	–	–	–	–	WITH RANGING ONLY
	12	.9	–	–	–	
	13	–	1.3	–	–	
	14	1.3	–	–	–	WITH RANGING
	15	–	1.3	–	–	WITH RANGING

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